MARTIAN BASALT (SHERGOTTITE) QUE94201 AND LUNAR BASALT 15555: A TALE OF TWO PYROXENES.

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Introduction. QUE94201 is a recently discovered Antarctic shergottite [1], which appears to be most similar to the highly evolved dark, mottled lithology described from Zagami [2]. However, pyroxenes in this meteorite exhibit growth features that are quite different from those in the other basaltic shergottites, but are similar to those in certain lunar basalts [3,4]. Specifically, these pyroxenes consist of cores of magnesian pigeonite that are mantled by magnesian augite, followed by rims of ferroan pigeonite that are strongly zoned to pyroxferroite. Such zonation patterns have, in fact, been reproduced in pyroxenes that have grown continuously in controlled cooling rate experiments on lunar basalt compositions [5,6]. However, these patterns in the QUE94201 pyroxenes have been interpreted by different authors as either indicative of single-stage, progressive crystallization [3] or complex, multi-stage growth [7,8].

In this study, our goal is to resolve the issue of single- vs. multi-stage crystallization history for the QUE94201 shergottite by comparing trace and minor element zonation features in pyroxenes of this martian basalt with those in a lunar basalt (i) with pyroxenes having similar growth features and (ii) for which a single-stage crystallization history has been established. Such a lunar basalt is 15555 [9,10]. Although 15555 is an olivine-normative basalt, the crystallization sequence of its major minerals (after early crystallization of olivine) appears to have been similar to that of QUE94201, and this should be reflected in the behavior of the minor and trace elements. We have, therefore, made *in situ* ion microprobe determinations of trace and minor element concentrations in pyroxenes of this lunar basalt, and made additional analyses on QUE94201 pyroxenes to complement those previously reported by us [11].

Results. Pyroxenes of 15555 and QUE94201 show extensive zonation in minor and trace elements. Fig. 1 reports V vs. Fe abundances of pigeonite cores and ferroan pigeonite rims. Note that the trends defined by the data for pigeonites of both basalts overlap. Also, V concentrations decrease steadily as Fe abundances increase and the transition between the pigeonite core and rim compositions is smooth and continuous. Cr behaves similarly to V, although Cr concentrations in pigeonites of 15555 appear to be slightly but systematically higher. Al concentrations decrease sharply with increasing Fe abundances in pigeonite cores in 15555 and QUE94201, but the trends for the data appear to "flatten" at higher Fe concentrations for the pigeonite rims (Fig. 2); Al abundances are systematically higher for pigeonites of 15555 than for those of QUE94201. Zr abundances in pigeonites of 15555 and QUE94201 increase smoothly with increasing Fe concentrations, although the slope of the trend defined by the data for the lunar basalt is steeper. The trace elements for which the behavior is the most different for pigeonites of 15555 and QUE94201 are the REEs and Y. Fig. 3a shows that Y (and, by analogy, REE) abundances increase steadily with increasing Fe concentrations in pigeonites of lunar basalt 15555. However, while Y concentrations also increase with increasing Fe abundances in pigeonite cores of QUE94201, they decrease sharply in pigeonite rims, which have higher Fe concentrations (Fig. 3b). In augites of QUE94201, the abundances of V, Cr, Al are anti-correlated with Fe concentrations, while those of Zr, Y and the REEs are positively correlated. (Note: Symbols in all figures are the same as those in Fig. 1; line drawn through the data indicates the progressive crystallization trend.)

Discussion. The similarity of zonation trends for elements such as V, Cr and Al in pigeonites of the lunar basalt 15555 and the martian basalt QUE94201 indicates that the petrogenetic histories of these two rock types were indeed very similar, at least when the major minerals pyroxene and plagioclase were crystallizing. Further, the smooth transition between trace and minor element compositions of pigeonite cores and rims in both of these rocks (Figs. 1 and 2) supports a single-stage cooling history wherein the minerals comprising these rocks formed as the result of continuous, progressive crystal-lization of their respective parent melts.

The anti-correlation between Al and Fe concentrations in the pigeonite cores and in augites of QUE94201 suggests that plagioclase was co-crystallizing with these pyroxenes for a major portion of the crystallization history of this rock. However, the flattening of the Al vs. Fe trends defined by the data for the ferroan pigeonite rims (Fig. 2) indicates that these rims were formed subsequent to the cessation of plagioclase crystallization. The main difference between the growth histories of the lunar and martian basaltic samples considered here occurred towards the end of crystallization. This is evident from Fig. 3, which shows the sharp drop in the concentration of Y (by a factor of ~2.5) from the most Fe-rich pigeonite core composition to the most Fe-poor ferroan pigeonite rim composition in QUE94201; in contrast, Y concentrations continue to increase dramatically (and continuously) from the magnesian pigeonite core to the ferroan pigeonite rim compositions of 15555. Further, Y is positively correlated with Fe in augites in QUE94201. This indicates that, in QUE94201, whitlockite began crystallizing immediately after the formation of magnesian pigeonite cores and augite mantles whereas, in 15555, whitlockite did not begin its crystallization until much later, i.e., after the formation of the ferroan pigeonite rims. This is consistent with the much higher abundance of whitlockite in QUE94201 than lunar basalt 15555, which most likely reflects the difference in the P contents of their respective parent melts.

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